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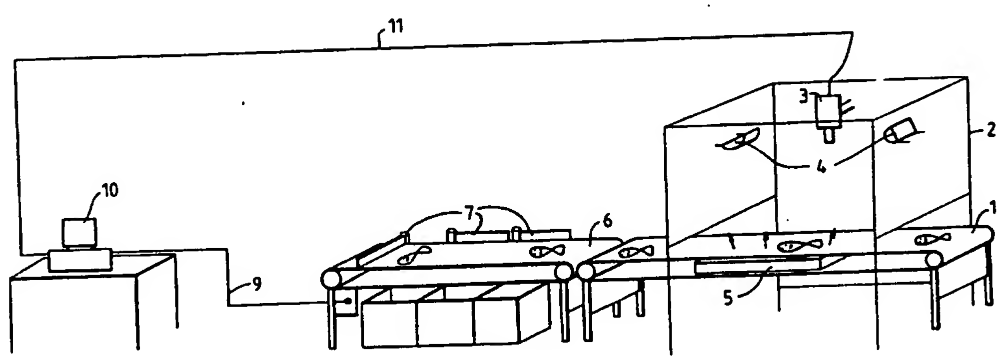

(57) Abstract

A fish sortring apparatus comprising a conveyor belt (1) for carrying one or more rows of fish parallel to its direction of travel, a means (4) for illuminating the fish, a colour video camera (3), a video memory having a number of storage areas connected to the video camera (3), a means for storing the camera derived image values of a fish from the one or more rows in a storage area of the memory, a means for determining edge values of the image and storing them, a means for using the stored edge values to generate shape descriptors the values of which are stored and compared with those already in the memory or the logic of a computer processor (10) associated therewith, and a means for determining the colour and/or light intensity of predetermined areas within the image periphery and storing and comparing values therefor with those stored in the memory. The descriptors are subject to descriminant analysis whereby a signal is generated corresponding to the score derived from the analysis such that fish on the conveyor are deflected into a desired reception area.

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FISH SORTING MACHINE.

The present invention relates to an apparatus for sorting flexible food products, particularly fish, and a method for operating that apparatus. Particularly provided is an apparatus capable of sorting fish into species or groups thereof on the basis of shape and colour.

The provision of apparatus for automatically sorting fish by species, size and weight, for example on board fishing or factory vessels, makes it possible to automate the collection of data on catch and discards. This has important implications for management of fish stocks and operation of the common fisheries policy.

The need for automatic sorting of fish by species has been discussed by Tayama et al (Reito (Tokyo) Refrigeration Vol. 57 No. 661 (1982) pp. 1146-1150; Shimdate, M. Mitsubishi Denki Hiko (Tokyo). Vol. 56 No. 3 (1982) pp. 44-48.), Wagner et al (Lebensmittelindustrie Vol.30 No.8 (1983) pp. 375-376.;Lebensmittelindustrie Vol. 34 No.1 (1987) pp. 20-23. and Strachan et al (Pattern Recognition Vol. 23 No. 5 (1990) pp. 539-544.; 'Computer Vision for the fish industry' edited by Pau, L.F. and Olafsson, R., Marcel Decker (1992)).

These researchers have described the shape of fish by length measurements, where length is defined as a horizontal straight line from the tip of the head to the base of the tail; and by width measurements where width is defined as the distance from the top to the bottom of the body measured at a number of equidistant points along the length. They found that they could sort 4 species of fish with a reliability of 95% and 7 species with an accuracy of 90%. A further suitable apparatus for carrying out simple fish sorting using aspect ratio and area ratio is described in EP 0331390.

For a sorting machine to be used on board a fishing vessel, up to 30 species of fish may have to be sorted with a reliability of 99%. It

is therefore necessary to use not only shape but also variables such as colour or shading to provide additional sorting information.

Colour has been used for image analysis and pattern recognition, for example to identify spray paint caps (Berry, D.T. Pattern Recognition Letters Vol. 6 (1987) pp. 69-75), to detect the colour codes on resistors (Bajon et al. 'Identification of multicoloured objects using a vision module' Robot Vision and Sensory Control. 6th Int. Conf. Paris, France. Vol. 10 (1986) pp. 21-30) and to guide a robot to selectively pick up petri dishes (Massen et al Proc. Int. Conf. Robot Vision and Sensory Controls (1988). pp. 115-122)). Colour has also been used to segment images into sets of uniform colour regions (Tominaga. Proc. 4th Int. Conf. on Pattern Recognition, Cambridge, UK (1988) pp. 163-172; Celenk. 'An adaptive machine learning algorithm for colour image analysis and processing' Int. Conf. on Manufacturing Systems and Technology, Cambridge, HA, USA (1987) No. 4 pp. 403-412; Klinker et al ; SPIE Applications of Artificial Intelligence. 937 (1988) pp. 229-244). and to detect edges in images (Nevatia. 'A colour edge detector' 3rd Int. Joint Conf. on Pattern Recognition, Coronado, California, USA (1976) pp. 829-837).

The aim of the present invention is to provide an apparatus for automated colour based sorting of irregular objects, eg. fish, which is capable of being integrated with a shape descriptor system, eg apparatus, into a system for sorting fish by species. An improved shape descriptor system is also provided whereby the orientation of the fish with respect to its front and back ends may be automatically asessed and thus all other descriptors related to that.

In order to facilitate comparison of input descriptors with reference descriptors in an automatic apparatus it is necessary to store the latter in some form which can readily be referred to by automatic, particularly electronic, means. Such reference descriptors are thus

most conveniently stored as values in a computer memory or logic.

There are approximately 30 species of demersal and 5 of pelagic fish landed in Scotland (Department of Agriculture and Fisheries for Scotland 'Scottish Sea Fisheries Statistical Tables 1988'. Crown Copyright (1989) 57 pp.). A preferred apparatus according to the invention sorts pelagic and demersal fish species and treats them separately. This is convenient because they live in different parts of the water column, demersal living on or near the seabed and pelagic mainly in shoals near the surface, and hence they are unlikely to be caught together.

The preferred apparatus of the present invention, and the method for operating it, have been shown to be effective in experiments sorting 5 species of pelagic fish and 18 species of demersal fish; these latter 18 species representing more than 95% of all demersal fish landed in Scotland. The invention offers a reliability of sorting the 18 species of demersal fish of 100% and of the 5 species of pelagic fish of 98%. This presents a significant improvement over all other results so far published, these quoting a sorting accuracy of only 90-95% for 4-7 species of fish.

The present invention provides an apparatus for indicating the type of a fish comprising a means for receiving light from the fish and generating an image of it in the form of a set of values therefrom, a means for storing the set of values in a computer memory, a means for assigning the values to areas of the image, and a means for using these to determine and indicate the type of the fish, characterised in that the apparatus comprises a means for determining values indicative of the colour of all or some of the areas of the fish and that the type of fish is indicated by means which compares values indicative of colour by area with predetermined such values stored in the memory or a processor associated therewith, these being characteristic of a particular type of fish, and a means which designates the fish as that

type having stored values to which the determined values correspond.

Most advantageously the indication is used to direct the fish to a predetermined reception area associated with the type of fish with which it is designated to most closely correspond and the apparatus thus is incorporated as part of an apparatus for automatically sorting fish.

Most preferably the orientation of the fish with respect to which end is that of the head and which is that of the tail is determined. This is conveniently carried out by a novel method which determines the width of the image at two points set a distance between each end and the mid length of the fish image respectively, particularly about one tenth of the total fish image length in from each end, as determined in linear unbent form. Using this method the larger width measurement is indicative of the head end.

Similarly, the orientation of a flat fish with respect to whether it is top or belly side up may be assessed by interpreting colour as indicative of the eye side surface and lack of colour as indicative of the reverse side. With round fish such as cod, haddock, whiting and saithe the upper half of the fish is always darker than the lower half. Both head/tail and top/bottom orientation determination offer significant advantage in identifying the fish by the present method.

More preferably the present invention comprises an apparatus for indicating the type of a fish comprising

(a) a means for storing one or more sets of values indicative of predetermined length, widths and areas, and the distribution of colour and/or light intensity in these areas, each set characteristic of an image of a particular type of fish

(b) means for receiving the image of a fish, the type of

which is to be indicated, in a camera;

(c) means for receiving the image from the camera in the form of a set of values and storing these in a memory means;

(d) means for determining boundary values of the image of the fish;

(e) means for determining values representing predetermined lengths, widths and/or areas of the image and their ratios,

(f) means for determining values indicative of colour of predetermined areas of the image,

(g) means for determining which end of the image is representative of the front end and which is representative of the back end of the fish and/or means for determining which is the upper and which is the lower surface of the fish, and comparing the oriented values from (d) (e) and (f) with corresponding values stored in the means (a) as characteristic of a particular sort of fish;

(h) indicating means which indicates the type of fish to be that having stored values corresponding with the determined values.

Most advantageously the indication (h) is used to direct fish to a predetermined sorting area associated with their type.

The means for determining the front and back end preferably uses the length and width data derived by (e) to carry out the method described above based upon width measurements taken at each of two points, one between each end and the mid-length, preferably at about one tenth of the distance from each end. The means for determining top and bottom surfaces preferably uses the values indicative of colour of predetermined areas derived by (f) to carry out the method described above whereby the darker or coloured surface is designated the top.

Thus in a preferred embodiment the present invention provides a sorting apparatus comprising an apparatus as described in either of the embodiments above wherein the fish are presented to a camera, eg. on a conveyor, and their ratios of predetermined length, widths and/or areas, and values indicative of the colour of all or some of the areas, as derived from the fish images produced by that camera, are used to classify the fish, thus generating a control signal which directs the fish to an appropriate destination. Using preferred embodiments of the present invention it is possible to indicate the type of a fish when that fish may be presented in a variety of forms due to its flexibility and deformability, ie. to indicate the type of fish and preferably to direct the fish to an appropriate destination.

A particular form of apparatus of the present invention comprises a conveyor belt for carrying one or more rows of fish, preferably in rows parallel or perpendicular to its direction of travel, a means for illuminating the fish, a colour video camera, a memory having a number of storage areas connected to the video camera output, a means for storing the camera derived image values of the illuminated fish from the one or more rows in a storage area of the memory, a means for determining the image size and orientation from stored edge values, a means for using the stored edge values to generate shape descriptors the values of which are stored and compared with those already in the memory or the logic of a computer processor associated therewith, and a means for determining the colour of predetermined areas within the image periphery and storing and comparing values therefor with those stored in the memory or the logic.

One suitable such means for determining shape descriptors and dividing the image up into length, width and area values is described in EP 0331390, wherein values are stored and transferred between bit planes.

Typically apparatus of the present invention will comprise a colour video camera with red, green and blue signal outputs connected to a

computer memory whereby a pattern of pixels corresponding to the image to be analysed can be produced. This memory is connected to a processor for generating the finite elements of aspect and area ratios and the average red, green and blue values of selected parts of the image. These elements, or descriptors, are compared with values previously generated, eg. from calibration of the apparatus using a number of fish of known type, ie. fish of known species, or built into the computer logic, and a score generated indicative of whether or not the fish is of a given type, eg. species.

It is preferred to determine the length, width and/or area values of the fish by back-lighting it in the image receiving step. This is conveniently achieved by use of a light source mounted below the fish as it is presented to the means for receiving the image, ie. the camera. Where a conveyor belt is used this is conveniently made of a material which transmits at least a proportion of light emitted from a source placed below it such that back-lighting can be achieved thereby providing a distinct silhouette.

It is preferred to determine the colour values of the fish by front-lighting the object in the image-receiving step. This is particularly advantageously carried out using diffuse light generated by directing light from one or more light sources onto a reflective surface from which it passes onto the top of the object. Conveniently the reflective surface is the inside a a housing in which the image receiving means, eg. video camera, is mounted. Preferably the reflective surface is of white colouration. The preferred method of operating the apparatus of the invention calibrates the camera outputs to normalise them before operation.

It will be realised by those skilled in the art that signals generated by the computer can readily be used to operate a series of deflectors on a conveyor belt to deflect a fish to its determined sorting destination where all fish of that type will be deflected to.

TABLE 1: The groups of Aspect ratio and Area Ratio that are used to classify fish into various groups according to the method of the invention for use with the apparatus of the invention, including the two main groups (Groups 1 and 2) requiring colour analysis

All Fish	Fish of Aspect ratio	Fish of Area ratio
	>0.40	>0.40 (Group 1 herein)
Angler fish	Angler fish	Dab
Catfish	Dab	Flounder
Cod	Flounder	Lemon Sole
Coley	Lemon Sole	Megrim
Dab	Megrim	Plaice
Flounder	Plaice	Redfish
Haddock	Redfish	Sole
Hake	Skate	Witch
Lemon Sole	Sole	
Ling	Witch	0.20-0.40
Megrim		Angler fish
Plaice	0.20-0.40	
Red mullet	(Group 2 herein)	
Redfish	Catfish	<0.20
Skate	Cod	Skate
Sole	Coley	
Witch	Haddock	
Whiting	Hake	
	Red mullet	
	Redfish	
	Whiting	>0.80
	<0.20	Ling
	Hake	<0.80
	Ling	Hake

A method for operating the apparatus of the present invention is also provided based upon use of multivariate analysis, particularly discriminant analysis and is that disclosed in the Examples described below, although other multivariate data processing technoques such as neural networking may equally be applied with success. The apparatus and method of the present invention will now be illustrated with reference the non-limiting examples, Examples 1 to 3 below, further embodiments falling within the scope of the claims will occur to those skilled in the art in the light of these. Figures 1 to 8 are provided to illustrate aspects of the Examples.

FIGURES

Figure 1 shows a shape grid constructed for a whiting in two different positions, the grid being shown superimposed upon the fish silhouette.

Figure 2 shows a grid suitable for a flatfish as shown superimposed upon the silhouette of a lemon sole (upper image) and a megrim (lower image).

Figure 3 shows the position of one particular significant coloured area (shown as a light area) in the grid for a flounder, a group 1 fish by the method of Table 1.

Figure 4 shows the position of some particular significant coloured areas (shown as light areas) in the grids of catfish (upper silhouette) and cod (lower silhouette), group 2 fish by the scheme of Table 1.

Figure 5 shows the position of some particular significant coloured areas (shown as light areas) in the grids of herring (upper silhouette) and sprat (lower silhouette), pelagic fish.

Figure 6 shows a flow chart setting out the stages in determination of the type of fish from their images, backlit and frontlit, as provided

by an embodiment of apparatus of the invention and a method of operating it.

Figure 7 shows a diagrammatic representation of a perspective view of a fish sorting apparatus of the present invention.

Figure 8 shows a diagrammatic representation of the arrangement of the means for determining values indicative of colour of areas of the object in a preferred embodiment of the invention and its relationship to the other parts of the apparatus of Figure 7.

EXAMPLE 1: Apparatus of the invention and method of operating it.

A fish sorting apparatus according to the present invention (see Figure 7) was provided comprising quartz halogen lamps (4) GEC 300 W power with a colour temperature of 2854 K, placed in a housing (2) over a partially transparent conveyor belt (1). The interior of the housing was matt white in colour such that the light from the lamps (4) was reflected from its walls and ceiling to give the diffuse lighting that is required to reduce the amount of specular reflection from the glossy skin of the fish.

A video camera (3), Sony DXC 325PK three chip colour video camera, was suspended from the top of the housing and before operation of the apparatus the automatic gain control was switched off. The images of the fish passed before the camera were taken both backlit using a lightbox (5) placed between the runs of the conveyor to give the silhouette, and frontlit to give the colour. Red, Green and Blue values were fed from the camera to a computer arrangement (described below and in Figure 8) which was used to determine the various values from which descriminant analysis was used to determine fish type (species). Outputs from the computer (9) were used to selectively operate deflector elements (7) on a diverter conveyor (6) such that fish that had been typed were deflected into an appropriate one of

a number of species bins (8).

The colour values were obtained from the red, green and blue (RGB) outputs from the video camera. These signals were then digitised to eight bits per colour using a frame grabbing board (Imaging Technology Inc. or Sprynt Colour Input Board) and then stored on a computer workstation (486PC Sun 3-160C) where they were processed by an i860 CPU using algorithms written in the C programming language.

Colour Calibration: The black (R(b), G(b) and B(b)) and white (R(w), G(w) and B(w) camera output signal levels were obtained by lens capping and use of a reference white tile with the camera aperture set at f4 respectively. The red, green and blue (Rp, Gp, Bp) camera outputs were then normalised according to the black and white levels, using the following equations:

$$R = \frac{Rp - R(b)}{R(w) - R(b)} \times 100\% \qquad (1)$$

$$G = \frac{Gp - G(b)}{G(w) - G(b)} \times 100\% \qquad (2)$$

$$B = \frac{Bp - B(b)}{B(w) - B(b)} \times 100\% \qquad (3)$$

The calibration was done once a day using a Macbeth colour chart.

Simple Shape Descriptors. Two descriptors were used for crudely sorting the fish. The first was the aspect ratio (A_s),

$$A_s = \frac{w}{l} \qquad (4)$$

where w is the maximum width of the fish and l is the length of the fish from its nose to the end of its tail.

The second was the area ratio (A_r)

$$A_r = \frac{A_f}{A_b} \qquad (5)$$

where A_f is the area of the front half of the fish, from the head to the midpoint of the fish, and A_b is the area of the back half of the fish, from the tail to the midpoint of the fish.

Position Reference System and Shape Descriptors: Flatfish are fish with large aspect ratios (A_s > 0.40) and do not bend very much. But fish with small values (A_s < 0.40) bend and deform relatively easily (Webb and Weihs, 'Fish Biomechanics', Praeger Publishers, New York, USA. (1983)). To sort fish by species it is useful to analyse, for example, how the width changes along its length and the colouration across the fish. To do this a position reference coordinate system should be established which can accommodate fish deformations and bending.

Advantageously, the orientation of the fish with respect to which end is that of the head and which is that of the tail was determined. This was conveniently carried out by determining the width of the image at a distance of about one tenth of the total image length in from each end. Using this method the larger measurement is indicative of the head end. Similarly, the orientation of a flat fish with respect whether it was top or belly side up was assessed by interpreting colour as indicative of the eye side surface and lack of colour as indicative of the reverse side. With round fish such as cod, haddock, whiting and saithe the upper half of the fish is always darker than the lower half and this information is also usefully used

in orienting fish images.

For each fish image the computer processor was used to construct a grid, typically consisting 36 quadrilateral elements as in Fig 1. Strachan et al (J. Photographic Sci. 1990) have named this grid the 'shape grid' because it is derived from the shape of the fish. Shown is the shape grid for a whiting in two different deformation states showing that the grids bend with the fish.

For each fish type a shape grid was constructed as follows:

(i) The image of the fish silhouette was thresholded, made binary, the principal axis was found and the fish silhouette oriented on it horizontally (see Strachan: Pattern Recognition (1990) as above),

(ii) The width of the fish was determined at each point along its length by dropping vertical lines from its top edge to its bottom edge and the locus of the midpoints of these lines produced the central line of the grid,

(iii) From the width profile of the fish along its length the tip of the head and the narrowest point of the tail stalk were detected,

(iv) The central line was approximated at 10 segments of equal length joining the tip of the head to the narrowest point of the tail stalk

(v) The normals of the central line were drawn from each of the points joining these segments to both the upper and lower edge of the fish image,

(vi) Each normal (both upper and lower) was split into two equal segments, and

(vii) All of these segments were connected to produce the shape grid.

It can be seen that such a grid can be constructed to bend with the fish and thus is suitably constructed by a computer from values in a memory, ie. data in the form of pixels, representative of the image of a bent fish. The bent grid may be transformed into a straight grid or vice versa by processing with algorithms using method of Bookstein, Transformations of quadrilaterals, tensor fields, and morphogenesis. In P L Antonelli (Ed.) Mathematical Essays on Growth and the Emergence of Form. University of Alberta Press, Edmonton, Alberta (1985).

Such a grid is capable of overlapping itself and hence a different sort of grid is required for fish with large aspect ratios, ie. flatfish. The grid shown in Fig 2 is suitable for flatfish. It is constructed using vertical lines instead of normals to the central symmetry line. This grid will be poor at modelling the bending of fish but as has been mentioned already flatfish bend very little and hence this problem can be ignored.

From either type of shape grid a set of descriptors can be obtained to describe the shape of the fish. These were the 10 widths of the fish defined by the grids and the length of the fish from its nose to the apex of its tail. These shape descriptors were used to sort the fish by species.

Colour Descriptors: For the tail and the nose (which in the present example consists of the front four shape grid elements) and for each of the 36 other elements of the shape grid (or the simple shape grid), the average R, G and B values are determined. This produces 114 variables (36 elements plus nose and tail with average R, G, B in each = 38 x 3 = 114) which can be used to sort the fish by species.

Discriminant Analysis: Discriminant analysis (Nie et al 'Statistical package for the social sciences, 2nd ed., McGraw-Hill, New York, U.S.A. (1975).) is used to process the shape descriptor and the colour descriptor data derived from the image in the memory store,

employing linear combinations of variables to distinguish between the different species of fish.

The use of discriminant analysis requires the linear combination of the variables that best distinguishes between the different species of fish to be found and used by the processor that carries out the generation of the descriptors from the colour image. A stepwise method was used to generate discriminant functions by introducing one variable at a time. If the new function satisfied the discriminant analysis criterion then it was accepted. If not, it was rejected along with the last variable introduced.

At the end of this process the resulting classification coefficients C_{ij} (Fisher's linear discriminant functions) were obtained. C_i, the classification score for species group i, is given by a linear combination of C_{ij}'s:

$$C_i = \sum_{j=1}^{jmax} C_{ij}\, Q(j) + C_{io} \qquad (6)$$

where $i = 1,2 \ldots n$ (n = no of species of fish), C_{io} is a constant and the Q(j)'s are the raw values of the variables.

The variables that were used in Examples 1 to 3 are:

1. The eleven shape descriptors (jmax = 11)

2. The R, G, B average values of the nose and front third shape grid elements of the fish (jmax = 39)

3. The R, G, B average values of the middle third shape grid elements of the fish (jmax = 36)

4. The R, G, B average values of the tail and tail third shape grid elements of the fish (jmax = 39)

The colour descriptors were split into three subgroups because in any technique using multivariate analysis the analysis performs better if the number of variables is reduced (Digby, P.G.N. and Kempton, R.A. 'Multivariate Analysis of Ecological Communities'. Chapman and Hall, London, England (1987).

Since there were n species of fish, every new fish to be sorted for species was given n scores, one from each classification function. Fish were sorted as the species whose function had the highest score.

For the discriminant analysis the fish have to be split into two sets (the calibration and the test set). The species of the calibration set fish along with the variables is entered into the processor and from these the discriminant analysis algorithm produces the Fisher classification coefficients. The variables of the test set of fish are then introduced to the processor and this determines the species of these fish using the Fisher linear discriminant functions.

The arrangement of the processor with respect to the R, G, B input from the video camera and its associated equipment is shown in Figure 8. The R, G, B analog inputs from the camera are fed to respective 8 bit analog to digital converters connected in turn to look up tables and 2 megabytes of FIFO store. This store is accessed by a 64 bit data bus further connected to a video random access memory and a video monitor, an 8 megabyte DRAM and the central processing unit (CPU). The CPU has outputs which control the deflectors of the divertor conveyor.

In experiments carried out using apparatus configured as described in Example 1 and in Figures 5 to 7 there were at most 35 fish of each species, hence where possible 20 fish of each species are used as the calibration set. This is because the larger the calibration set the

better the discriminant analysis performs.

The aforesaid apparatus, with the processor programmed to carry out descriminant analyis as described was provided with fish of either Demersal (Example 2) or Pelagic (Example 3) types, these not usually requiring sorting together.

EXAMPLE 2: Apparatus for sorting Desmersal fish.

The apparatus was set up such that the computer processor first sorted images according to aspect ratio A_s and then according to their area ratio A_r (see Table 1 in introduction). This identified angler fish, skate, ling and hake. There remained two groups of fish which required further sorting. Group 1 consisted mainly of flat fish and some round fish which have large aspect ratios. Group 2 consisted exclusively of round fish. 18 fish species were sorted in total.

For Group 1 the simple shape grid was generated for each of the species of fish from which shape and colour descriptors were generated (example position of colour varying area shown in Fig 3) and these were subjected to discriminant analysis. For the calibration set the discriminant analysis sorted all of the fish (135 fish) correctly ie. 100% sorting reliability for the shape descriptors and the 3 sets of colour descriptors. For the test set of fish the shape descriptors had a sorting reliability of 94% (92 out of 98), the front third colour descriptors had a sorting reliability of 95% (93 out ot 98), the middle third colour descriptors had a sorting reliability of 95% (93 out of 98) and the tail third colour descriptors had a sorting reliability of 94% (92 out of 98). These four sets of results were combined by simply classifying a fish as the one most preferred by adding the results together. In doing this the sorting reliability

obtained was 100% (98 out of 98).

For the Group 2 fish the shape grid was used. From this the shape and colour descriptors were obtained (examples of colour varying areas shown in Fig 4) and these were then subjected to discriminant analysis. For the calibration set the discriminant analysis sorted all of the fish (117 fish) correctly, ie. a 100% sorting reliability for the shape descriptors and the 3 sets of colour descriptors. For the test set the shape descriptors had a sorting reliability of 90% (69 out of 77), the front third colour descriptors had a sorting reliability of 96% (74 out of 77), the middle third colour descriptors had a sorting reliability of 100% (77 out of 77) and the tail third colour descriptors had a sorting reliability of 100% (77 out of 77). When these four sets of results were combined as before a sorting reliability of 100% (77 out of 77) was obtained.

Hence the 18 species of demersal fish used in these experiments were sorted with a reliability of 100% (133/133 test fish).

Example 3: Apparatus for sorting Pelagic fish.

The five main species of pelagic fish have similar values of A_r and A_s therefore the procedure of Table 3 does not work on pelagic species.

Shape grid were generated for all of the pelagic fish and from these the shape and colour descriptors were calculated (see examples of position of colour varying areas Fig 5) and subjected to discriminant analysis. For the calibration set the discriminant analysis sorted all of the fish (80 fish) correctly ie a 100% sorting reliability for the shape descriptors and the 3 (front, middle and tail) sets of colour descriptors. For the test set of fish the shape descriptors had a sorting reliability of 98% (55 out of 56), the front third colour descriptors had a sorting reliability of 100% (56 out of 56), the middle third colour descriptors had a sorting reliability of 88%

(49 out of 56) and the tail third shape descriptors had a sorting reliability of 98% (55 out of 56). When these four sets of results were combined (as in the previous section) a sorting reliability of 98% (55 out of 56) was obtained. The one fish which was not classified correctly was a sprat and it was classified as 50% probability of being sprat and 50% herring.

CLAIMS.

1. An apparatus for indicating the type of a fish comprising a means for receiving light from the fish and generating an image of it in the form of a set of values therefrom, a means for storing the set of values in a computer memory, a means for assigning the values to areas of the image of the fish, and a means for using these to determine and indicate the type of the fish, characterised in that the apparatus comprises a means for determining values indicative of the colour of all or some of the areas of the fish and that the type of fish is indicated by a means which compares the values indicative of colour by area of the fish with predetermined such values stored in the memory or a processor associated with it, these being characteristic of a particular type of fish, and a means which designates the fish as that type having stored values to which the determined values correspond.

2. An apparatus as claimed in claim 1 wherein the indication is used to control a sorting mechanism for directing the fish to a predetermined reception area associated with the type of fish with which it is designated to most closely correspond.

3. An apparatus as claimed in claim 1 or claim 2 wherein the orientation of the image of the fish is determined with respect to which end is the front end of the fish and which is the back end and/or which is the upper surface and which is the lower surface, and the colour and shape descriptors are related to these.

4. An apparatus for indicating the type of a fish comprising

(a) a means for storing one or more sets of values indicative of predetermined length, widths and areas, and the distribution of colour in these areas, each set characteristic of an image of a particular sort of fish;

(b) means for receiving the image of a fish, the type of which is to be indicated, in a camera;

(c) means for receiving the image from the camera in the form of a set of values and storing these in a computer memory means;

(d) means for determining boundary values of the image of the fish;

(e) means for determining values representing predetermined lengths, widths and/or areas of the image and their ratios,

(f) means for determining values indicative of colour of predetermined areas of the image,

(g) means for determining which end of the image is representative of the front end and which is representative of the back end of the fish and/or means for determining which is the upper and which is the lower surface, and comparing the oriented values from (d) (e) and (f) with corresponding values stored in the means (a) as characteristic of a particular sort of fish;

(h) indicating means which indicates the type of fish to be that having stored values corresponding with the determined values.

5. An apparatus as claimed in claim 4 wherein the indication means controls a mechanisms which directs the fish to a predetermined sorting reception area associated with the type of fish.

6. A sorting apparatus as claimed in any one of claims 1 to 4 wherein the fish are presented to a camera and their ratios of predetermined length, widths and/or areas, and the values indicative of colour in all or some of the areas, as derived from the image produced by that camera, are used to classify the fish, thus generating a control signal which directs the fish to an appropriate destination.

7. An apparatus comprising a conveyor belt for carrying one or more rows of fish, a means for illuminating the fish, a colour video camera, a video memory having a number of storage areas connected to the video camera, a means for storing the camera derived image values of a fish from the one or more rows in a first storage area of the memory, a means for determining the image size and orientation from stored edge and/or colour values, a means for using the stored edge values to generate shape descriptors the values of which are stored and compared with those already in the memory or logic of a computer processor associated therewith, and a means for determining the colour and/or light intensity of predetermined areas within the image periphery and storing and comparing values therefor with those stored in the memory or logic.

8. An apparatus as claimed in any one of the preceding claims comprising a colour video camera with red, green and blue signal outputs connected to a computer memory whereby a pattern of pixels corresponding to the image to be analysed can be produced, a processor for generating the finite elements of aspect and area ratios and the average red, green and blue values of selected parts of the image, the processor being connected to the memory, a comparator for comparing these elements with values previously generated from calibration of the apparatus using a number of fish of known type and stored in the memory or incorporating in the logic of a processor associated therewith, and a means for generating a score indicative of the number whether or not the fish is of a given type.

9. An apparatus as claimed in any one of the preceding claims wherein the image of the fish is recorded by the camera under both backlit and frontlit lighting conditions.

10. An apparatus as claimed in any one of the preceding claims wherein signals from the red, green and blue (RGB) outputs from the video camera are digitised to eight bits per colour using a frame

grabbing board and then stored on a computer workstation where they are processed using algorithms.

11. An apparatus as claimed in any one of the preceding claims wherein the orientation of the fish with respect to which end is the head and which end is the tail is carried out by determining the width of the image at each of two points, each placed between a respective end and the mid-length of the image, and designating the larger width to be indicative of the head.

12. An apparatus as claimed in claim 11 wherein the two points are situated at a distance approximately one tenth of the total image length from each end.

13. An apparatus as claimed in any one of the preceding claims wherein the orientation of the fish with respect to which surface is the upper surface and which surface the lower surface is carried out by designating the lighter or less coloured surface the lower surface.

14. An apparatus as claimed in any one of the preceding claims wherein the image values are used to generate aspect ratio (A_s) and area ratio (A_r) shape descriptors.

15. An apparatus as claimed in claim 14 wherein those images having aspect ratios of over 0.40 are indicated as those of flatfish and those below 0.40 as roundfish.

16. An apparatus as claimed in claim 15 wherein the image of the fish has an aspect ratio of over 0.40 and is used to generate a grid constructed using vertical lines from the central line of symmetry.

17. An apparatus as claimed in claim 14 wherein the image of the fish has an aspect ratio less than 0.40 and is used to generate a grid of quadrilateral elements constructed from lines normal to its central line of symmetry.

18. An apparatus as claimed in either of claims 16 or 17 wherein the grid has a number of width values generated from the fishes nose to its tail.

19. An apparatus as claimed in any one of the preceding claims wherein the average R, G, B values of the image are determined for the tail, the nose and for some or all of the elements of the shape grid, having a computer processor which carries out multivariate analysis processing using these values as descriptor values for determining the species of the fish.

20. An apparatus as claimed in claim 19 wherein the width values are used as descriptor values for multivariate analysis processing wherein they are used to determine the species of the fish.

21. An apparatus as claimed in claim 19 or 20 wherein the linear combination of the variables that best distinguishes between the different species of fish to be sorted is installed in the logic of the processor that carries out the multivariate analysis.

22. An apparatus according to any one of claims 19 to 21 wherein the multivariate analysis is discriminant analysis.

23. An apparatus as claimed in any one of claims 19 to 22 wherein discriminant functions are generated by introducing one variable at a time wherein if the new function satisfies discriminant analysis criterion then it is accepted and if not, it is rejected along with the last variable introduced.

24. An apparatus as claimed in claim 23 wherein the classification score for species group i, is given by a linear combination of C_{ij}'s:

$$C_i = \sum_{j=1}^{jmax} C_i j\, Q(j) + C_{io} \qquad (6)$$

where i = 1,2 ... n (n = no of species of fish), C_{io} is a constant and the Q(j)'s are the raw values of the variables.

24. An apparatus as claimed in any one of claims 21 to 23 wherein the variables used comprise width shape descriptors, a length descriptor, the R, G, B average values of the nose and front third shape grid elements of the fish, the R, G, B average values of the middle third shape grid elements of the fish, and the R, G, B average values of the tail and tail third shape grid elements of the fish.

25. An apparatus as claimed in any one of claims 21 to 24 wherein fish to be sorted for species are given n scores, one from each classification function, and are sorted as the species whose function had the highest score.

26. An apparatus as claimed in claim 25 adapted such that when the species of a calibration set of fish inputted to the processor along with the variables, the discriminant analysis algorithm produces the Fisher classification coefficients, such that when the variables of the test set of fish are introduced to the processor it can determine the species of these fish using the Fisher linear discriminant functions.

27. An apparatus as claimed in any one of the preceding claims suitable for indicating type of and/or sorting desmersal fish characterised in that it first sorts the fish images according to aspect ratio (A_s), then according to area ratio (A_r), as defined herein, then subject to multivariate analysis.

28. An apparatus as claimed in any one of claims 1 to 27 substantially as described in any one of the Examples 1, 2 or 3.

29. A method for operating an apparatus as claimed in any one of the claims 1 to 27 substantially as described herein in any one of Examples 1, 2 or 3.

Fig.1(a).

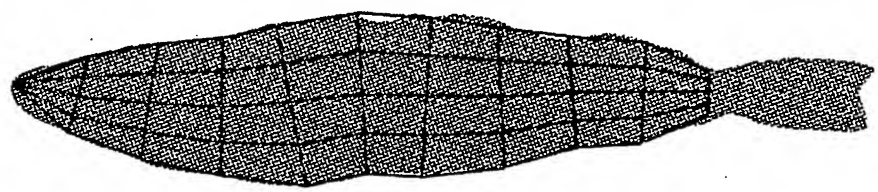


Fig.1(b).

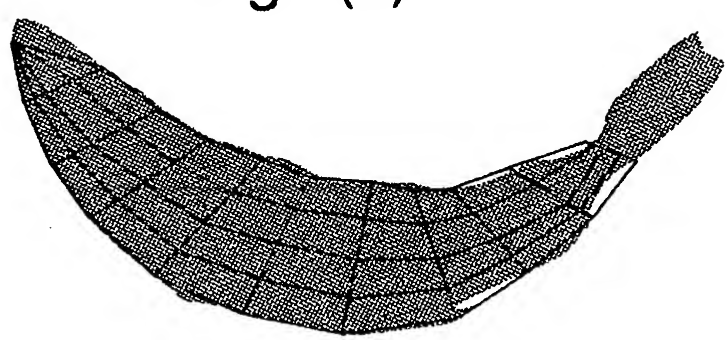
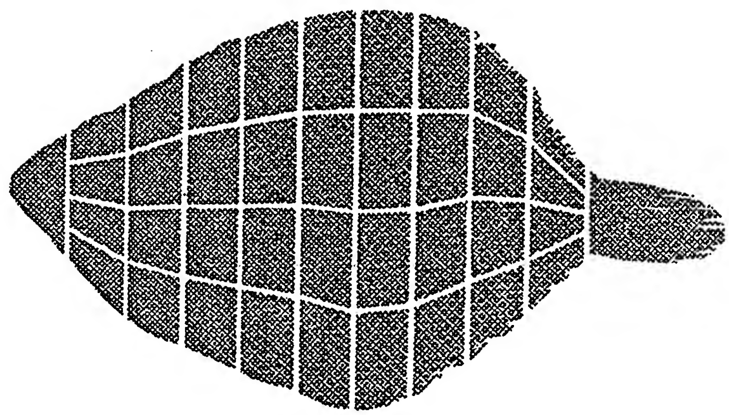


Fig.2.

LEMON SOLE



MEGRIM

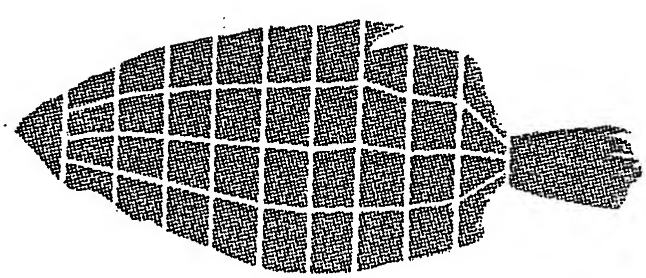


Fig.3.

FLOUNDER

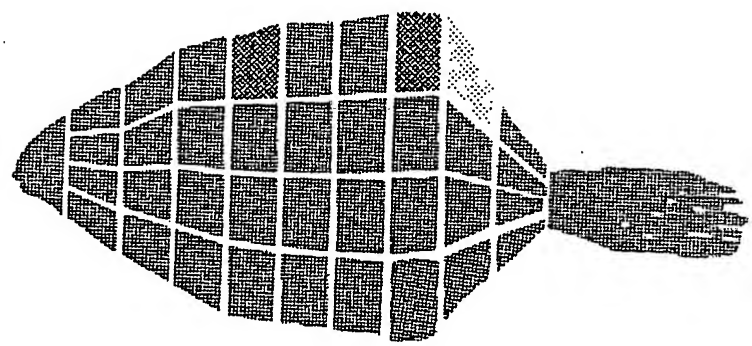
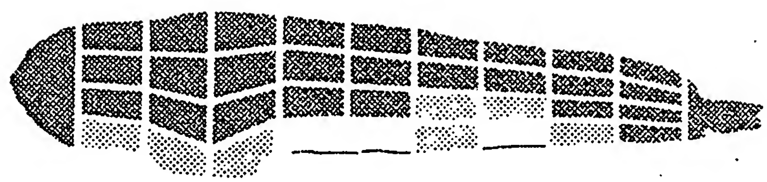


Fig.4.

CATFISH



COD

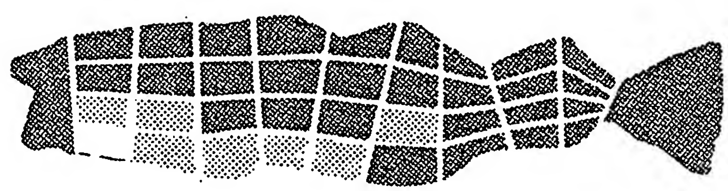
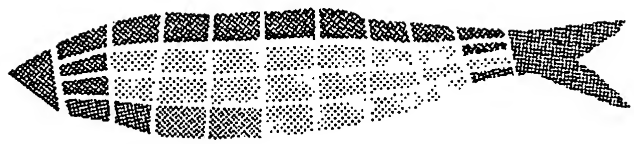
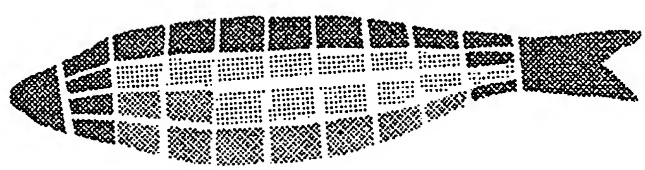


Fig.5

HERRING



SPRAT



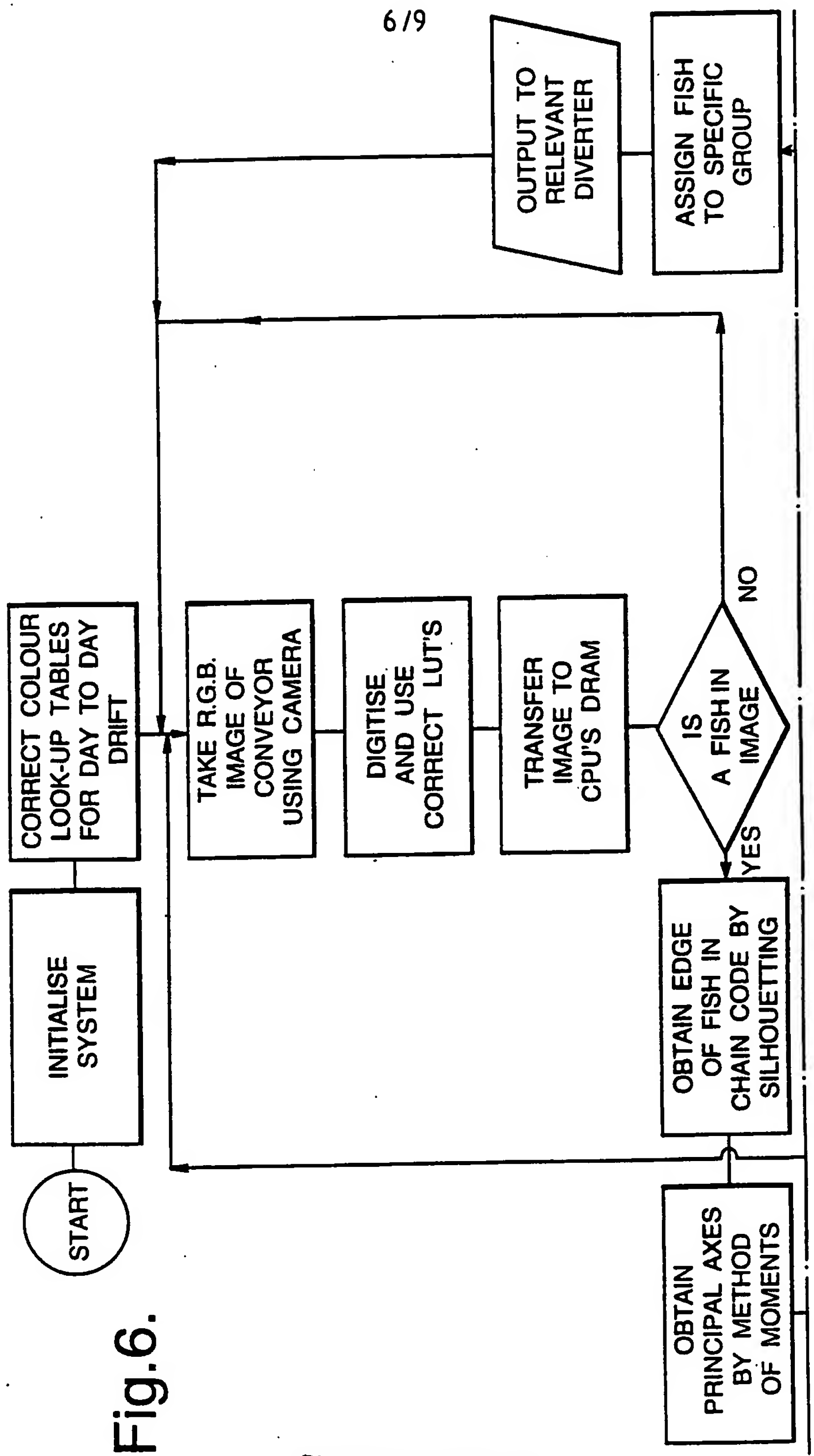

START
INITIALISE SYSTEM
CORRECT COLOUR LOOK-UP TABLES FOR DAY TO DAY DRIFT
TAKE R.G.B. IMAGE OF CONVEYOR USING CAMERA
DIGITISE AND USE CORRECT LUT'S
TRANSFER IMAGE TO CPU'S DRAM
IS A FISH IN IMAGE
NO
YES
OBTAIN EDGE OF FISH IN CHAIN CODE BY SILHOUETTING
OBTAIN PRINCIPAL AXES BY METHOD OF MOMENTS
ASSIGN FISH TO SPECIFIC GROUP
OUTPUT TO RELEVANT DIVERTER

Fig.6.

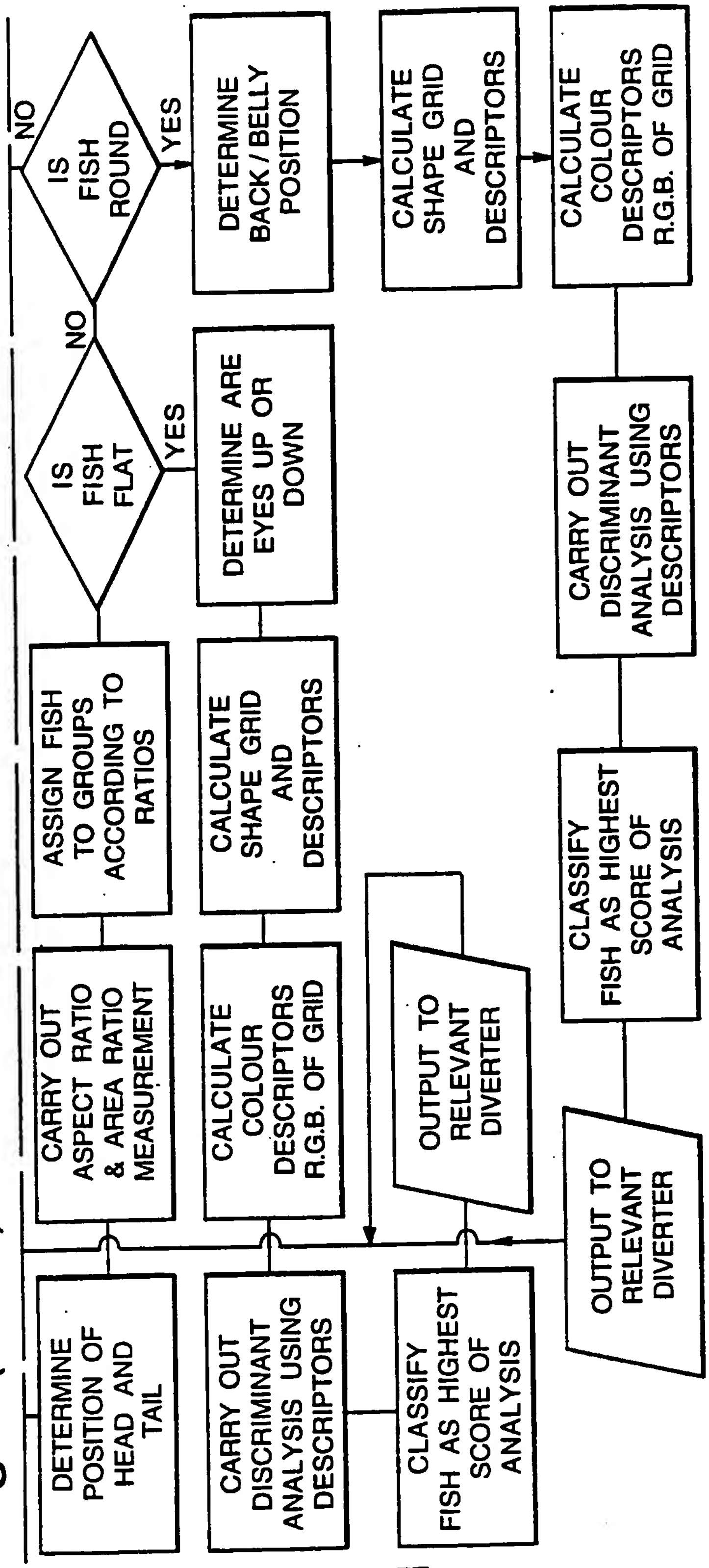

DETERMINE POSITION OF HEAD AND TAIL
CARRY OUT ASPECT RATIO & AREA RATIO MEASUREMENT
ASSIGN FISH TO GROUPS ACCORDING TO RATIOS
IS FISH FLAT
YES
NO
DETERMINE ARE EYES UP OR DOWN
CALCULATE SHAPE GRID AND DESCRIPTORS
CALCULATE COLOUR DESCRIPTORS R.G.B. OF GRID
CARRY OUT DISCRIMINANT ANALYSIS USING DESCRIPTORS
CLASSIFY FISH AS HIGHEST SCORE OF ANALYSIS
OUTPUT TO RELEVANT DIVERTER
IS FISH ROUND
YES
NO
DETERMINE BACK / BELLY POSITION
CALCULATE SHAPE GRID AND DESCRIPTORS
CALCULATE COLOUR DESCRIPTORS R.G.B. OF GRID
CARRY OUT DISCRIMINANT ANALYSIS USING DESCRIPTORS
CLASSIFY FISH AS HIGHEST SCORE OF ANALYSIS
OUTPUT TO RELEVANT DIVERTER

Fig.6 (Cont).

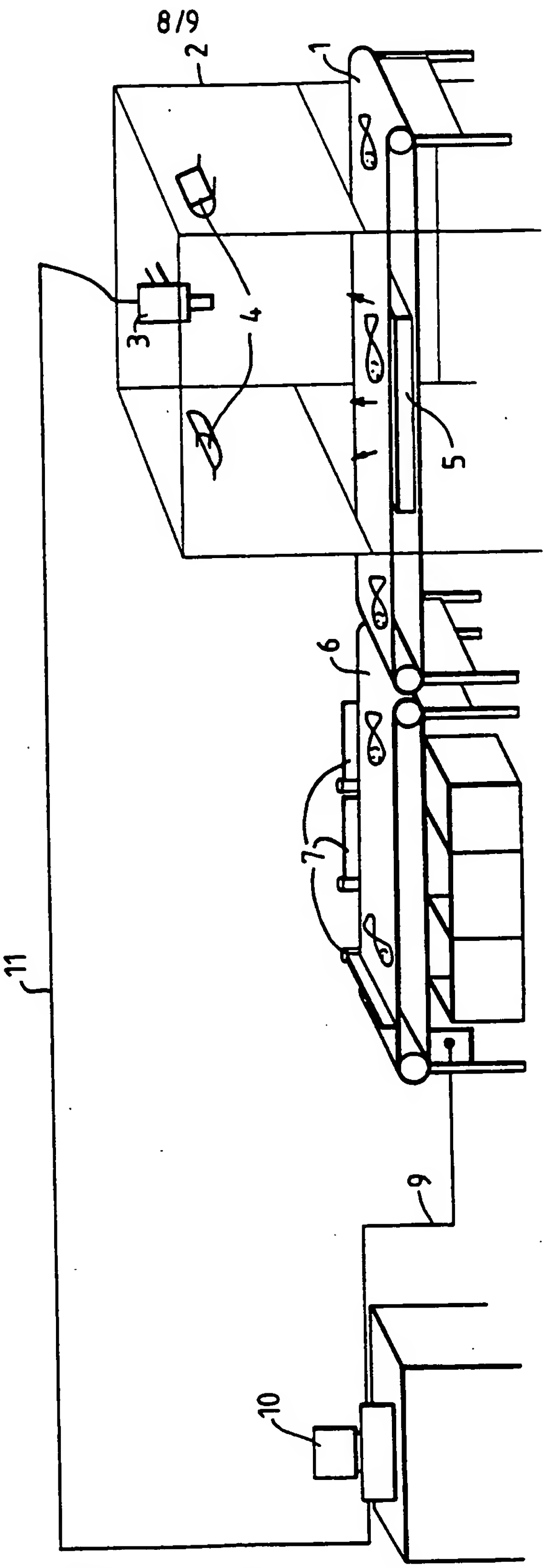


Fig.7.

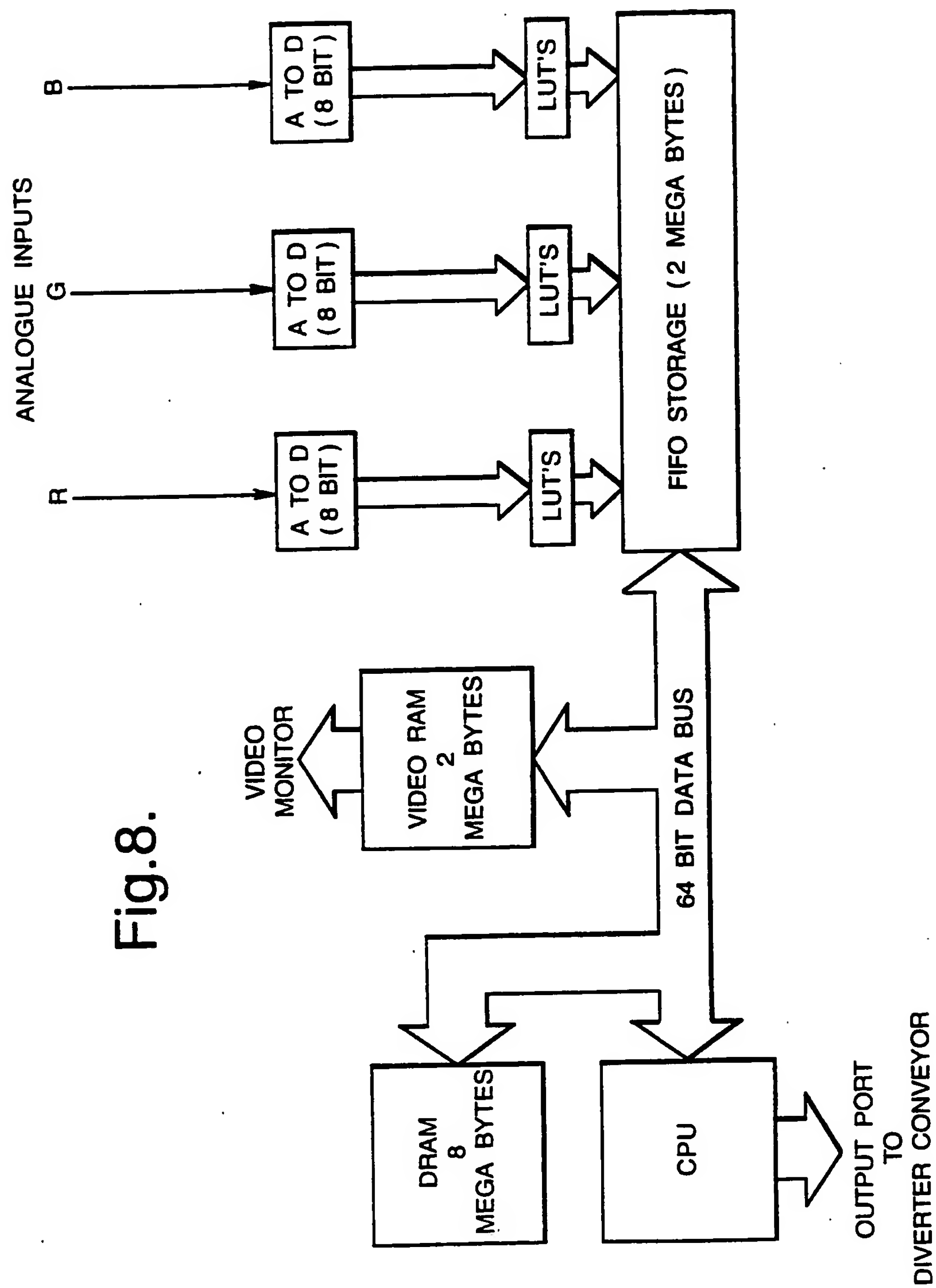

ANALOGUE INPUTS
R
G
B
A TO D (8 BIT)
A TO D (8 BIT)
A TO D (8 BIT)
LUT'S
LUT'S
LUT'S
FIFO STORAGE (2 MEGA BYTES)
64 BIT DATA BUS
VIDEO MONITOR
VIDEO RAM 2 MEGA BYTES
DRAM 8 MEGA BYTES
CPU
OUTPUT PORT TO DIVERTER CONVEYOR

Fig.8.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 93/02151

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^5: B 07 C 5/342,B 07 C 5/34,A 22 C 25/04,G 01 B 11/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^5	B 07 C,A 22 C,G 01 B,G 06 K

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	SOVIET INVENTIONS ILLUSTRATED, Ch section, week B41, November 21, 1979 DERWENT PUBLICATIONS LTD., London, SU-643 140 (TEKHRYBPROM EXPER) --	1,3,4, 7,11, 14
Y	EP, A2, 0 331 390 (GROVE TELECOMM.) 06 September 1989 (06.09.89), abstract; claims 1-12 (cited in the application). --	1,3,4, 7,11, 14
A	US, A, 5 085 325 (JONES et al.) 04 February 1992 (04.02.92), abstract; fig. 1; claims 1,6, 10,11,20. --	1,2,4-8,10, 19,23
A	PATTERN RECOGNITION, vol. 23,	1,3,6,

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
12 January 1994	28. 01. 94
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	FUSSY e.h.

International Application No PCT/GB 93/02151

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages	Relevant to Claim No.
	no. 5, issued 1990 (Oxford), STRACHAN N.J.C. et al. "Fish species recognition by shape analysis of images", pages 539-544, abstract; page 541, column 2 - page 542, column 2 (cited in the application). --	9,20-27
A	DE, A1, 4 204 843 (MAREL LTD.) 20 August 1992 (20.08.92), abstract; fig. 1; claims 1,3-5. ----	1,3,4,7-9

ANHANG | ANNEX | ANNEXE

zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

to the International Search Report to the International Patent Application No.

au rapport de recherche international relatif à la demande de brevet international n°

PCT/GB 93/02151 SAE 80842

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The Office is in no way liable for these particulars which are given merely for the purpose of information.

La présente annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche international visée ci-dessus. Les reseignements fournis sont donnés à titre indicatif et n'engagent pas la responsibilité de l'Office.

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
EP A2 331390	06-09-89	CA A1 1251863	28-03-89
		DK A0 933/89	27-02-89
		DK A 933/89	30-08-89
		EP A3 331390	11-04-90
		NO A0 890853	28-02-89
		NO A 890853	30-08-89
		NO B 167182	08-07-91
		US A 4963035	16-10-90
US A 5085325	04-02-92	keine - none - rien	
DE A1 4204843	20-08-92	DK A0 214/92	19-02-92
		DK A 214/92	20-08-92
		US A 5184733	09-02-93